Report and Recommendations to the Office of Mine Safety and Licensing

Mine Equipment Review Panel

November 2006

Kentucky
UNBRIDLED SPIRIT

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Executive Summary

Background

The Sago and Aracoma mine tragedies of January 2006 mobilized the mining community comprised of state and federal regulators, industry, and labor to seek ways to improve miner safety. In Kentucky, a legislative initiative took the form of the Omnibus Mine Safety Bill (Senate Bill 200). Senate Bill 200 strengthened the state's ability to enforce operator compliance with approved roof control and ventilation plans and mandated improvements in mine safety equipment and training that could improve the chances of escape or rescue for miners endangered in a mine fire or explosion. The bill passed the legislature unanimously and was signed into law by Governor Ernie Fletcher on April 21, 2006.

Among other provisions, Senate Bill 200 established the Mine Equipment Review Panel (Panel). The charge to the Panel as provided in Kentucky Revised Statutes (KRS) Chapter 351 is:

> *The Mine Equipment Review Panel shall be a permanent panel of recognized experts who shall review and make recommendations to the executive director of the Office of Mine Safety and Licensing regarding best available mine safety technologies, including but not limited to wireless tracking and communications devices for use by miners in underground mines. Based on the recommendations provided by the panel, the executive director shall comprise a list of commercially available mine safety equipment, including wireless tracking and communications devices that may be approved for use by coal miners.*
>
> *The Mine Equipment Review Panel shall provide initial recommendations to the executive director of the Office of Mine Safety and Licensing not more than one hundred twenty (120) days after the panel members have been appointed and the panel is duly constituted to conduct business. Periodically, the panel shall review*

and make recommendations to the executive director on changes to or innovations in mine safety equipment that could be deployed in coal mines.

The membership of the Mine Equipment Review Panel is specified in statute to include representatives of the National Institute of Occupational Safety and Health (NIOSH), the federal Mine Safety and Health Administration (MSHA), the coal industry, labor represented by the United Mine Workers of America (UMWA), the Department of Mining Engineering at the University of Kentucky, and the Executive Director of the Office of Mine Safety and Licensing (OMSL). The representatives currently appointed to the panel are Tim Watkins, MSHA; Mark Watson, Alliance Coal; Edgar "Butch" Oldham, UMWA; Dr. Joseph Sottile, Department of Mining Engineering, University of Kentucky, and Johnny Greene, Acting Executive Director, OMSL. Robert Hardman served as the MSHA representative prior to his appointment to District Manager, District 4, in Mt. Hope, West Virginia.

The Panel was initially convened on July 31, 2006. The initial meeting was dedicated to discussion of the charge to the panel and selection of priority topics. Four topics were selected for further review:

- Wireless Tracking and Communications Devices
- Self-Contained Self-Rescuers
- Mine Refuge Chambers
- Mine Seals

In addition to the four initial topics of consideration, the Panel chose to make recommendations on related safety concerns relative to the funding of mine safety research and development and training.

The panel met on seven occasions to hear presentations on current and developing mine equipment technologies and to formulate consensus recommendations. The panel was fortunate to receive input from subject matter experts on state-of-the art safety equipment and technological advancements. The work of the Mine Equipment Review

Panel is ongoing. It was with great foresight that the legislature established the Panel on a permanent basis in light of the dynamic state of mine safety equipment development. The Panel has identified an ongoing need to evaluate technological advancements in several fields that have the potential to improve the safety of Kentucky's coal miners.

Recommendations

Wireless Tracking and Communications Devices

- The Panel has determined that no commercially available MSHA approved wireless communication or tracking system currently meets the requirements for post accident communications established under the federal MINER Act. Developments associated with wireless communication and tracking systems in the mining industry are very dynamic with new communication and tracking technologies and refinements to existing technologies continually being assessed in the mining environment. The MINER Act requirement to establish wireless two-way communications and to provide electronic tracking systems within three years of enactment serves as the driving force for development of new communication and tracking devices. As such, the Panel recommends no legislative action at the state level to mandate wireless communication and tracking systems at this time. The Panel will continue to review and monitor wireless communication and tracking technology at least semi-annually or as significant developments in the technology occur.

Self-Contained Self-Rescuers

- The Panel recommends that self-contained self-rescuer training more closely simulate emergency conditions and to include instruction on proper donning, switching from one unit to another, how the unit functions and the actions a miner can take to maximize duration of a unit. Training devices should be developed to simulate breathing resistance and heat generation commonly experienced with chemically-generated oxygen units. Training should emphasize care and

inspection of self-contained self-rescuer units in accordance with manufacturer's recommendations. This expanded training should be part of annual refresher training and should be stressed throughout the year as a part of routine safety meetings.

- The federal MINER Act established a requirement to cache self-contained self-rescuers at a distance of no further than an average miner could walk in 30 minutes. Kentucky Senate Bill 200 adopted MSHA standards for storage cache locations. The 30 minute spacing standard is based upon a 50 percent safety margin, whereby current approved 60 minute SCSR device duration ratings are discounted by 50 percent. Through the establishment of a predetermined 30 minute spacing requirement, incentive to develop longer rated self-contained self-rescuers has been eliminated. The federal 30 minute spacing standard should be modified to reflect a time equivalent to 50 percent of a SCSR device's approved duration rating to provide an incentive for the development of longer duration self-rescuers.

- The requirement to attach an intrinsically safe strobe light device to self-contained self rescuer storage caches may have unintended consequences by creating a potential ignition hazard if the unit were damaged in a mine accident or explosion. KRS 352.133 should be amended to remove the requirement for a strobe light device. In the event of a mine emergency, the presence of a damaged strobe light under power could require mine rescue teams to retreat from the mine, delaying rescue operations. The presence of reflective signs attached to each cache provides means for escaping miners to locate stored self-contained self rescuers. Additionally, required lifelines should be installed in a manner to direct miners to storage caches in the event of an emergency.

- The Panel recommends the establishment of reporting requirements for inoperative or nonfunctional self-contained self-rescuers removed from service for reasons other than damage associated with normal mine use. Reporting standards for licensees should include a minimum of manufacturer, model, serial

number, and circumstance of removal with reports to be filed with the Office of Mine Safety and Licensing within 10 days of occurrence. Reporting of defective self-contained self-rescuers will aid the Office of Mine Safety and Licensing in tracking SCSR reliability and performance.

Mine Refuge Chambers

- New miner training and annual refresher training must emphasize that the use of a barricade or mine refuge chamber is a measure of last resort. It is imperative that miners must make every attempt to escape the mine in the event of an emergency.

- The federal MINER Act requires each coal mine operator to implement an accident preparedness and response plan to provide for the maintenance of individuals trapped underground. The plan must make provisions for a post-accident breathable air supply, rapidly deployable barricades, tools, food, water, first-aid materials, gas detectors, and permissible light sources. In addition, the MINER Act directs the National Institute of Occupational Safety and Health (NIOSH) to research the utility, practicality, and survivability of various refuge alternatives in an underground mine environment, including field tests. NIOSH is to report upon the research findings within 18 months of enactment of the MINER Act, at which time the Secretary of Labor must develop a course of action, including any proposed federal regulations.

  The Panel has determined that no commercially available mine refuge chambers currently meet the demands of Kentucky operations relative to seam height restrictions, physiology limitations, and overall chamber survivability. The Panel recommends no legislative action at the state level to mandate mine refuge chambers at this time, based upon the federal requirement for interim measures for the maintenance of trapped miners and the lack of a federal design standard. The Panel will continue to review and monitor developments associated with mine refuge chambers at least semi-annually or as further developments occur.

Mine Seals

- The Office of Mine Safety and Licensing and MSHA have initiated inspection and monitoring programs to evaluate existing alternative mine seals designed to the previous 20 psi overpressure standard. Under inspection and monitoring programs, operators are required to document the condition of existing alternative mine seals and sample the atmosphere behind the seal. Remedial actions are not required if an alternative mine seal is in sound physical condition, properly constructed, and the mine atmosphere behind the seal is inert (less than 3 percent methane or more than 20 percent methane). If an alternative mine seal is in poor condition, damaged, or the mine atmosphere behind the seal contains from 3 percent to 20 percent methane, the operator must take remedial actions such as inerting the atmosphere, increasing the capacity of the existing seal, or the construction of a conventional Mitchell-Barrett mine seal. The Panel concurs with the overall inspection and monitoring program for existing alternative mine seals yet recommends continued periodic sampling of the atmosphere behind alternative seals by the operator to establish trending for individual seals.

- Mine management should be required to certify construction of mine seals in accordance with approved plans and regulations. MSHA Procedure Instruction Letter No. I-06-V-09 requires alternative seal construction, installation and materials to be certified by senior mine management (mine superintendent, or other equivalent mine official). The requirement to certify construction of alternative mine seals should be expanded to include conventional Mitchell-Barrett mine seals as safety concerns associated with improper seal construction exist regardless of seal type.

Related Safety Concerns

- The federal government and the Commonwealth of Kentucky need to develop a long-term funding mechanism to ensure continued research and development in the critical fields of mine safety and mine rescue technology. With the demise of

the U.S. Bureau of Mines in 1996, the mining industry lost a centralized clearing house for many mining research initiatives. In this vacuum many areas of research, such as wireless mine communications, have not significantly advanced since initially analyzed by the Bureau in the preceding decades. The mining industry itself is a relatively small market which severely limits research and development funding in the private sector. Further complicating technological advancements are the numerous steps required to acquire regulatory certification prior to bringing a new product to market. There is a clear need for significant government funding of research and development of emerging mine safety technologies.

- The federal MINER Act established the Brookwood-Sago Mine Safety Grant program to award competitive grants for education and training. Grants are to be utilized for education and training programs to better identify, avoid, and prevent unsafe working conditions in and around mines. The Congressional Budget Office's review of the MINER Act provisions anticipates funding of approximately $1 million annually over 2007-2011. This anticipated level of federal funding falls well short of the amount needed to further mine safety education and training efforts. The Panel recommends the federal government and the Commonwealth of Kentucky secure additional funding for the development of innovative miner education programs.

Wireless Tracking and Communications Devices

Background

Presentations to the Kentucky Mine Equipment Review Panel demonstrated both the potential and the limitations of commercially available tracking and underground communications systems. To be effective, a mine communication system must provide reliable two-way communications and function in the event of a mine emergency. Likewise, an effective tracking system must provide real time data relative to a miner's location. Current communication and tracking systems remain dependent upon the integrity of cables and antennas, subject to damage by fire or explosion.

Developments associated with wireless communication and tracking systems in the mining industry are very dynamic with new communication and tracking technologies and refinements to existing technologies continually being assessed in the mining environment. The MINER Act requirement to establish wireless two-way communications and to provide electronic tracking systems within three years of enactment serves as the driving force for development of new communication and tracking devices.

In completing its charge to evaluate the best available wireless tracking and communications technologies, the Panel consulted with leading researchers and reviewed multiple product designs. The Mine Safety and Health Administration recently summarized currently approved underground communication and tracking systems as follows:

Handheld Two-Way Radios

General Information: Handheld, portable radios (walkie-talkies) are two-way radio transceivers widely used by consumers and can also be engineered for use in industry and more rugged working environments, including underground mines.

Pros:

- *These systems are currently available and are MSHA approved.*
- *Handheld walkie-talkies have the capability of providing two-way voice communication.*
- *Flexibility can be provided for use (frequency range and number of channels).*

Cons:

- *These frequencies cannot penetrate rock due to the high level of attenuation that they suffer. Communication is problematic if the devices aren't within "line of sight" of each other.*
- *Limited range; typically about 500 ft.*

Leaky Feeder Communication Systems

General Information: "Leaky Feeder" systems are two-way radio systems that feature a base station on the surface that communicates with individual underground radio units, such as walkie-talkie radios. To allow radio frequencies to function underground, it is necessary to replace a standard surface antenna system with a cable network. The cable networks should be installed to effectively radiate the signal throughout the mine. The cable is designed to "leak" signal, which allows radio transmissions to both leak from the cable and also enter the cable. The systems are generally used for both data and voice communications.

Pros:

- *These systems are currently available and are MSHA approved.*
- *Leaky feeder systems have the capability of providing two-way voice communication.*

Cons:

- *The main limitation is based on the frequency band for two-way voice, data and video is VHF. These frequencies cannot penetrate rock due to the high level of attenuation that they suffer. Communication is problematic if the devices aren't within "line of sight" of each other. An example of this problem is the inability of a commercial radio signal to broadcast through tunnels. Therefore, the walkie-*

talkie user must be fairly near the underground leaky feeder cable network to adequately communicate with the system.

- *The cables are subject to damage, which can disable the system.*

Mine Page Phones

General Information: Paging telephones are self-contained battery-powered communication units that provide loudspeaker paging and handset party line conversation over a two-conductor telephone line. In general, they operate from 12 volt DC lantern batteries. When paging, the user's voice can be heard via loudspeaker at all telephones connected to the system.

There is no practical limit to the number of units which can be connected to a paging telephone system. The units can be placed miles apart or as close together as a few feet. The system arrangement need not be on a loop basis, but can include branch circuits as required for convenience.

Pros:

- *These systems are currently available and are MSHA approved.*
- *Paging telephones have the capability of providing two-way voice communication wherever telephone lines are installed.*
- *Mature technology with simple and familiar operation.*
- *The units are relatively immune to interference from other electrical systems.*
- *Small portable units are available, which connect to the telephone lines with alligator clips.*

Cons:

- *The cables are subject to damage, which can disable portions of the system.*
- *The lantern batteries can be subject to frequent replacement.*
- *Most units are not carried by the user, but mounted at permanent or temporary fixed sites, requiring the user to be at the device to communicate.*
- *To use the small portable units, one must find and connect to the telephone line, which may be difficult in an emergency.*

Radio Frequency Identification (RFID) Tracking Systems

General Information: RFID tracking systems enable the identification of a miner's location in an underground mine. The miner wears a transmitter, which sends out a unique pulsed signal that is received by a receiver "reader". This is a mature technology that is just recently being introduced into underground United States mines.

- *Requires hard wire data and power connections.*
- *The readers are not MSHA approved (therefore, not intrinsically safe) but could be placed in explosion proof boxes.*

Pros:

- *If the system is disrupted, it still could provide the last recorded location of all personnel and equipment underground.*

Cons:

- *System is subject to damage from fire and explosion which could compromise the ability to track personnel or vehicles.*
- *The tracking accuracy is limited by the number of installed readers. The range of the readers is typically limited to approximately 200 feet. Therefore, if the readers are spaced (as commonly done) at 3000' intervals, a signal is received when the transmitter passes within 200' of reader A, but then not again until it passes within 200' of reader B. If the system is disrupted in an emergency and personnel need to be located, this limitation would create a potential search window of approximately ½ mile.*

PED System - Mine Site Technologies

General Information: The PED system is a one-way "Personal Emergency Device", a communication system featuring a belt-wearable receiving unit for individual miners. Mine Site Technologies was issued MSHA Approval for the Model PED1 Paging Receiver/Cap Lamp, meaning that this system may be marketed for use and used in underground gassy atmospheres. The system generally consists of a transmitter capable

of sending communications that can be received as a text message by miners through their PED. The PED system is currently used at about a dozen U.S. underground mines and has also been deployed at mines in other countries, particularly Australia.

- *It utilizes either a surface or underground antenna loop which radiates a radio frequency signal enabling one way communication to the underground workings.*
- *System dims and flashes lamp for about 10 seconds then sends a text message to the wearer. Individual, group or broadcast messages can be sent.*
- *There is only one US mine currently using the surface antenna.*
- *The problem of using a surface antenna is a logistical one mainly with the terrain.*
- *The maximum amount of cover for a surface antenna to be effective is about 2500' - 3000'.*
- *There have been a couple of success stories with respect to use in US mines, Willow Creek being the primary one.*
- *The system is MSHA approved for use on Koehler, MSA and Northern Lights [Canadian Manufacturer] cap lamps.*
- *Battery life - normally 8-12 hours but if lamp is turned off this time could be extended to days.*

Pros:

- *System enables communication of text messages from a central control center on the surface to miners underground. It uses a through the earth transmission system. The transmitting antenna can be installed either underground or on the surface. If installed on the surface, the system does not depend on any underground wiring.*
- *The system is relatively easy to use. It can convey a text message of up to 32 characters.*
- *The PED receiver is attached to the miner's cap lamp battery. This ensures the receiver is always with the miner.*
- *System has the potential of providing messages to miners during the early stages of a mine fire including evacuation instructions.*
- *Can be retrofitted with existing cap lamp manufacturers lamps, Koehler, NLT and MSA.*

- *System can be deployed in an emergency by stringing antenna cable on the surface thus enabling one way communication from the surface in some cases. This deployment may take time, however.*

Cons:

- *Installations incorporating underground antenna loops may be compromised in the event of a fire or explosion preventing communications.*
- *Systems employing underground antenna loops are not intrinsically safe and power must be removed in the event of a fan outage or other incidents such as mine fires and explosions, thus disrupting communication capability.*
- *The PED System only provides one-way communication from a person sending a message to a person receiving a message. The person sending the message receives no confirmation that the message was received.*

Emerging wireless communication and tracking technologies need to be evaluated in the real world mining environment. MSHA recently sponsored a series of tests of promising wireless technologies that might be adapted for use in underground mines. The selected prototype systems included wireless mesh networks, ultra-wide band radio, and very low frequency through-the-earth technologies. The underground field tests evaluated signal propagation, though-the-earth overburden penetration, overall system performance, and tracking system accuracy. In general, further study and system development was recommended as the geometry of mine entries, the presence of metallic structures, and interference from existing communication and electrical systems were found to degrade current wireless capabilities.

While several developing technologies show promise, the consensus of the panel was that no commercially available tracking or two-way underground communications technology currently meets the requirements of the MINER Act for wireless communications or real time tracking.

Panel members Butch Oldham, Mark Watson inspecting PED receivers

Recommendations

- The Panel has determined that no commercially available MSHA approved wireless communication or tracking system currently meets the requirements for post accident communications established under the federal MINER Act. Developments associated with wireless communication and tracking systems in the mining industry are very dynamic with new communication and tracking technologies and refinements to existing technologies continually being assessed in the mining environment. The MINER Act requirement to establish wireless two-way communications and to provide electronic tracking systems within three years of enactment serves as the driving force for development of new communication and tracking devices. As such, the Panel recommends no legislative action at the state level to mandate wireless communication and tracking systems at this time. The Panel will continue to review and monitor wireless communication and tracking technology at least semi-annually or as significant developments in the technology occur.

Self-Contained Self-Rescuers

Background

Self-contained self-rescuers (SCSRs) were first introduced into U.S. mining operations in 1981. The first generation SCSRs were typically cached, based on their overall size and weight, and were used in conjunction with belt wearable filter self-rescuers which only provided carbon monoxide scrubbing. Current belt wearable second generation SCSRs were introduced in 1989. Three manufacturers (CSE, Draeger, and Ocenco) produce 60 minute SCSRs approved for use in the U.S. market. The belt wearable CSE SR-100 and Draeger OXY K-Plus units produce oxygen through a chemical reaction while the cached Ocenco EBA 6.5 unit provides compressed oxygen.

CSE SR-100 and Draeger OXY K-Plus SCSR units generate oxygen through a chemical reaction of exhaled water vapor and potassium oxide. This reaction releases oxygen while capturing carbon dioxide. Oxygen generation and carbon dioxide capture is limited only by the volume of chemicals contained within the unit. Exhaled air is scrubbed of carbon dioxide and mixed with oxygen in a breathing bag. Oxygen production is dependent upon a miner's breathing rate and the amount of exhaled water vapor.

CSE SR-100 SCSR deployed and cased - NIOSH

Draeger OXY K-Plus SCSR cased and deployed - NIOSH

The Ocenco EBA 6.5 unit utilizes compressed oxygen stored in cylinders coupled with a chemical component for carbon dioxide removal. The amount of oxygen the units can supply is solely a function of the pressure rating for the cylinder. Exhaled air is scrubbed of carbon dioxide and mixed with oxygen in a breathing bag.

Ocenco EBA 6.5 SCSR cased and deployed - NIOSH

Training

Escape is the primary survival strategy in the event of a mine emergency. Proper donning and use of self-contained self-rescuers are the critical factors in a miner's ability to escape a toxic mine atmosphere. Mine fire and explosion reports have documented the fatal inability of miners to fully exploit the lifesaving capabilities of SCSRs. Miners unfamiliar with the heat, resistance and discomfort of breathing with an SCSR may discard a properly functioning unit under the mistaken impression that the unit has malfunctioned. Training devices need to be developed to simulate breathing resistance and heat generation commonly experienced with chemically-generated oxygen units.

Miners must have a better understanding of the capabilities and limitations of SCSRs and confidence in their own ability to don and utilize a unit in the event of an emergency. The key to improving a miner's confidence is hands-on training in simulated emergency conditions. Additionally, training must emphasize care and inspection of self-contained self-rescuer units in accordance with manufacturer's recommendations. Recent focused inspections by Office of Mine Safety and Licensing identified and removed from service 134 damaged SCSR units with visible signs of heat, water, seal, or impact damage.

The Office of Mine Safety and Licensing should initiate a reporting system for inoperative or nonfunctional self-contained self-rescuers removed from service for reasons other than damage associated with normal mine use. Without data relative to deployed SCSRs, there is no ability to monitor overall unit performance and identify trends which could lead to early warning of problems.

SCSR Storage Caches

The MINER Act requires each operator to develop an Accident Preparedness and Response Plan to provide for the evacuation of all individuals endangered by an emergency. In addition to the two SCSRs provided on the section for each miner as

required by the MSHA emergency temporary standard, the plan must provide for storage of SCSRs at 30 minute intervals in escapeways. MSHA interprets the MINER Act phrase that "caches of self-rescuers providing in the aggregate not less than 2 hours per miner to be kept in escapeways from the deepest work area to the surface at a distance of no further than an average miner could walk in 30 minutes" to mean that one-hour of oxygen per miner should be provided at each SCSR storage location in each escapeway. Kentucky statute KRS 352.133 requires caches to be maintained in sufficient numbers and locations determined in accordance with the most recent rules, standards, and regulations issued by the United States Mine Safety and Health Administration.

The distance a miner can travel in an escapeway in an emergency is generally based on:

- Disorientation / indecision
- Visibility
- Miner's overall fitness
- Anxiety level
- Entry height
- Debris in entries

The 30 minute federal spacing standard is based upon a 50 percent safety margin, whereby current approved 60 minute SCSR device duration ratings are discounted by 50 percent. The Panel expressed concerns that the establishment of a predetermined 30 minute spacing requirement eliminates incentive to develop longer rated self-contained self-rescuers. The federal 30 minute spacing standard should be modified to reflect a time equivalent to 50 percent of a SCSR device's approved duration rating to provide an incentive for the development of longer duration self-rescuers.

Kentucky statute KRS 352.133 requires SCSR storage caches to be identified with intrinsically safe strobe light devices which operate continuously or are capable of activation in the event of a mine emergency. This requirement may have unintended consequences by creating a potential ignition hazard if the unit were damaged in a mine

accident or explosion. In the event of a mine emergency, the presence of a damaged strobe light under power could require mine rescue teams to retreat from the mine, delaying rescue operations.

Recommendations

- The Panel recommends that self-contained self-rescuer training more closely simulate emergency conditions and to include instruction on proper donning, switching from one unit to another, how the unit functions and the actions a miner can take to maximize duration of a unit. Training devices should be developed to simulate breathing resistance and heat generation commonly experienced with chemically-generated oxygen units. Training should emphasize care and inspection of self-contained self-rescuer units in accordance with manufacturer's recommendations. This expanded training should be part of annual refresher training and should be stressed throughout the year as a part of routine safety meetings.

- The federal MINER Act established a requirement to cache self-contained self-rescuers at a distance of no further than an average miner could walk in 30 minutes. Kentucky Senate Bill 200 adopted MSHA standards for storage cache locations. The 30 minute spacing standard is based upon a 50 percent safety margin, whereby current approved 60 minute SCSR device duration ratings are discounted by 50 percent. Through the establishment of a predetermined 30 minute spacing requirement, incentive to develop longer rated self-contained self-rescuers has been eliminated. The federal 30 minute spacing standard should be modified to reflect a time equivalent to 50 percent of a SCSR device's approved duration rating to provide an incentive for the development of longer duration self-rescuers.

- The requirement to attach an intrinsically safe strobe light device to self-contained self rescuer storage caches may have unintended consequences by creating a

potential ignition hazard if the unit were damaged in a mine accident or explosion. KRS 352.133 should be amended to remove the requirement for a strobe light device. In the event of a mine emergency, the presence of a damaged strobe light under power could require mine rescue teams to retreat from the mine, delaying rescue operations. The presence of reflective signs attached to each cache provides means for escaping miners to locate stored self-contained self rescuers. Additionally, required lifelines should be installed in a manner to direct miners to storage caches in the event of an emergency.

- The Panel recommends the establishment of reporting requirements for inoperative or nonfunctional self-contained self-rescuers removed from service for reasons other than damage associated with normal mine use. Reporting standards for licensees should include a minimum of manufacturer, model, serial number, and circumstance of removal with reports to be filed with the Office of Mine Safety and Licensing within 10 days of occurrence. Reporting of defective self-contained self-rescuers will aid the Office of Mine Safety and Licensing in tracking SCSR reliability and performance.

Mine Refuge Chambers

Background

In reviewing mine refuge chambers, the Kentucky Mine Equipment Review Panel consulted with state and federal experts in chamber design as well as various chamber manufacturers. Refuge chamber design involves a series of tradeoffs that balance weight and durability vs. portability, chamber volume vs. available safe air supply through storage, scrubbing or external sources. There are three basic refuge chamber design concepts – built in place, rigid / hard walled, and soft walled / inflatable units.

A built-in-place refuge chamber utilizes the coal seam itself for construction by cutting a stub entry into the seam and closing the opening with an air-tight seal. As an alternative, a crosscut could be enclosed through the construction of two air-tight seals. Built-in-place chambers would be required to be constructed at routine intervals as the mine advances.

Rigid or hard-walled refuge chambers are portable enclosures typically constructed of steel or fiberglass. In larger seam heights, the units are generally pre-assembled. In lower seam heights, the units may be collapsed, requiring assembly prior to use.

Soft-walled or inflatable units are typically stored in a hardened skid unit for protection prior to a mine emergency. The units would be deployed if miners were unable to escape the working section. Soft-walled units are constructed of air-tight fabric and inflated with compressed air. Soft-walled / inflatable units are not designed to withstand secondary explosions or fires.

Kennedy Chamber Rigid / Hard-Walled Mine Refuge Chamber

Interior of Kennedy Chamber Rigid / Hard-Walled Mine Refuge Chamber

SUMMARY TABLE												
MANUFACTURERS	CAPACITY	INFLATABLE	STEEL	FABRIC	FILTERED MINE AIR	OXYGEN CYLINDERS	OXYGEN CANDLES	COMPRESSED AIR	CHEMICAL OTHER	AIR CONDITIONING	BATTERY PACK	NEED PERMISSIBILITY IS APPROVAL
Air Systems International Inc.	*	X		X				X				X
ChemBio Shelter, Inc.	18*	X		X			X		X			X
Cowan Mfg, Pty, Ltd.	*		X		X	X				X	X	X
Draeger Safety Inc.	20*		X			X		X		X	X	X
Gamma Services, International	16*								X	X		X
Jack Kennedy Metal Products (Panel-type)	23*		X			X						X
Jack Kennedy Metal Products (Prefab)	*		X			X						X
MineARC Systems	8-20*		X		X	X	X			X	X	X
Modern Mine Safety Supply, LLC	*		X							X	X	X
Shairzal Safety Engineering	4-40*		X		X	X	X	X	X	X	X	X
Strata Products USA	5-15*	X		X		X						X
* Units can be customized to accommodate different capacities												

Summary of commercially available mine refuge chambers - MSHA Technical Support Approval & Certification Center, Applied Engineering Division.

At a minimum, mine refuge chamber design must account for:

- Human Physiology
  - Oxygen Supply
  - CO_2 Scrubbing
  - Heat Dissipation
- Structural integrity of the chamber/barricade units (fire, heat, secondary explosion)
- Security and storage of emergency supplies
- Shelf life of equipment and supplies
- Handling and transport of chamber/barricade units
- Maintenance and periodic testing of chamber/barricade units
- Approval criteria / Permissibility of electrical components
- Communication options

Advancements in mine refuge chamber technology alone will not necessarily address safety concerns in the event of a mine emergency. Mine safety training must parallel the emphasis placed on the development and utilization of new mine safety equipment. New miner training and annual refresher training must emphasize that in the event of an emergency, miners must make every attempt to escape a mine and that the use of a barricade or mine refuge chamber is a measure of last resort.

Performance Standards

In the absence of a federal design standard for mine refuge chambers, the Kentucky Mine Equipment Review Panel reviewed the West Virginia Mine Safety Technology Task Force recommended performance standards. The West Virginia Task Force standards were developed utilizing a scenario based upon the review of actual mine explosion and fire events. Until such time a federal design standard is finalized, the Panel endorses the West Virginia performance standards.

Based upon the Task Force's scenario it is recommended that in order to be approved the Director determine that each proposed emergency shelter/chamber:

- *provide a minimum of 48 hours life support (air, water, emergency medical supplies, and food) for the maximum number of miners reasonably expected on the working section;*
- *be capable of surviving an initial event with a peak overpressure of 15 psi and a flash temperature of 300 degrees Fahrenheit;*
- *be constructed such that it will withstand normal handling and pre-event mine conditions;*
- *provide for rapidly establishing an internal shelter atmosphere of*
    - *O_2 above 19.5%,*
    - *CO_2 below 0.5%,*
    - *CO below 50 ppm, and*
    - *an apparent-temperature not exceeding 95 degrees Fahrenheit;*

- *provide the ability to monitor carbon monoxide and oxygen inside and outside the shelter/chamber;*
- *provide a means for entry and exit that maintains the integrity of the internal atmosphere;*
- *provide a means for intrinsically safe power if required;*
- *provide a minimum of eight quarts of water per miner;*
- *provide a minimum of 4000 calories of food per miner;*
- *provide a means for disposal of human waste to the outside of the shelter/chamber;*
- *provide a first aid or EMT kit in addition to a section first aid kit;*
- *have provisions for inspection of the chamber/shelter and contents;*
- *contain manufacturer recommended repair materials;*
- *provide a battery-powered internal strobe light visible from the outside indicating occupancy;*
- *provide a means of communications to the surface; and*
- *only contain MSHA approved materials where applicable.*

Utilizing the West Virginia performance standards, the Kentucky Mine Equipment Review Panel reviewed multiple design concepts and commercially available refuge units for use in Kentucky mine operations. Several design limitations were identified, i.e., seam height restrictions, physiology limitations, and overall chamber survivability. Field testing of refuge chamber designs should be implemented to assure the utility, practicality, and survivability of refuge alternatives in an underground mine environment.

Seam Height

In Kentucky, low seam heights are a primary design impediment. Rigid / hard walled refuge chambers have a practical height limitation of approximately 42". Storage skids for prototype soft walled / inflatable refuge chamber units reviewed by the Panel

were in the range of 28" – 30" in overall height. Several additional inches of clearance must be allowed for the transport and general mobility of any refuge unit.

Based on 2006 underground mine license data for a total of 261 underground mining operations, Kentucky has 37 active mines in seam heights of 30" or less. Of this number, 10 operations are mining in seam heights of 26" or less (predominantly Blue Gem Seam operations in the Barbourville District).

Kentucky Underground Mine License Data	
Seam Height	Number of Operations
49" or greater	51
43" to 48"	47
37" to 42"	67
31" to 36"	59
30" or less	37
Total	261

Survivability / Mobility

Refuge chamber design involves a series of tradeoffs that balance weight and durability vs. portability. Initial review of commercially available rigid / hard walled refuge chambers calls into question the ability of the unit to survive a potential mine explosion (15 psi overpressurization standard). Further strengthening of rigid units through steel reinforcement would significantly increase weight and limit overall mobility.

Human Physiology

In addition to providing an oxygen supply, food and water, a refuge chamber must meet human physiology environmental needs relative to temperature and humidity. Heat dissipation can be a limiting design factor in refuge chamber design. The West Virginia Mine Safety Technology Task Force adopted an apparent-temperature performance standard of 95 degrees Fahrenheit. Each individual miner will generate approximately

400 BTU per hour while the chamber is occupied. In addition, many of the proposed CO_2 scrubbing processes rely on exothermic chemical reactions further adding to chamber heating. Potential high temperatures can be further compounded by high humidity in a sealed environment. Heat dissipation is generally a factor of refuge chamber surface area, that is the amount of surface area that can react with the ambient mine atmosphere. The development of powered air conditioning solutions will be limited by approval / permissibility requirements.

Regulatory Developments

The federal MINER Act directs the National Institute of Occupational Safety and Health (NIOSH) to research the utility, practicality, and survivability of various refuge alternatives in an underground mine environment, including field tests. NIOSH is to report upon the research findings within 18 months of enactment of the MINER Act, at which time the Secretary of Labor must develop a course of action, including any proposed federal regulations.

Additionally, the MINER Act requires each operator to provide for the maintenance of miners not able to evacuate a mine in the event of an emergency. MSHA Program Policy Letter No. P06-V-10 requirements are as follows:

> *To provide for the maintenance of miners trapped underground, the ERP should include the following for each working section:*
>
> 1. *Two inflatable stoppings or other quick deployable barricade units should be provided within 6 months of becoming commercially available. Until these units are available, sufficient barricading materials to construct two air-tight barricades; the barricading material shall, at a minimum, include 4 brattice boards equal to the entry width, brattice cloth, sealant material, eight roof jacks, powered spad gun with sufficient spads, trowel and protective gloves, two claw hammers and nails, and 240 pounds of rock dust;*

2. *Inflatable shelters or equivalent may be used in lieu of barricading materials or other quick deployable units;*
3. *Food and potable water sufficient for a sustained period of time; and*
4. *First-aid kits, blankets, multi-gas detectors, and chemical light-sticks or other effective permissible light sources.*

Recommendations

- New miner training and annual refresher training must emphasize that the use of a barricade or mine refuge chamber is a measure of last resort. It is imperative that miners must make every attempt to escape the mine in the event of an emergency.

- The federal MINER Act requires each coal mine operator to implement an accident preparedness and response plan to provide for the maintenance of individuals trapped underground. The plan must make provisions for a post-accident breathable air supply, rapidly deployable barricades, tools, food, water, first-aid materials, gas detectors, and permissible light sources. In addition, the MINER Act directs the National Institute of Occupational Safety and Health (NIOSH) to research the utility, practicality, and survivability of various refuge alternatives in an underground mine environment, including field tests. NIOSH is to report upon the research findings within 18 months of enactment of the MINER Act, at which time the Secretary of Labor must develop a course of action, including any proposed federal regulations.

  The Panel has determined that no commercially available mine refuge chambers currently meet the demands of Kentucky operations relative to seam height restrictions, physiology limitations, and overall chamber survivability. The Panel recommends no legislative action at the state level to mandate mine refuge chambers at this time, based upon the federal requirement for interim measures for the maintenance of trapped miners and the lack of a federal design standard.

The Panel will continue to review and monitor developments associated with mine refuge chambers at least semi-annually or as further developments occur.

Mine Seals

Background

Preliminary accident information from the Sago and Kentucky Darby mines has raised questions relative to the construction and efficacy of alternative mine seals designed to the federal regulatory 20 psi static horizontal pressure standard. Adequate seals are crucial to contain explosions and prevent potentially explosive or toxic gasses from migrating into active working areas of underground coal mines.

By federal regulation 30 CFR § 75.335 a (Mitchell-Barrett) mine seal shall be:

i. Constructed of solid concrete blocks at least 6 by 8 by 16 inches, laid in a transverse pattern with mortar between all joints;
ii. Hitched into solid ribs to a depth of at least 4 inches and hitched at least 4 inches into the floor;
iii. At least 16 inches thick. When the thickness of the seal is less than 24 inches and the width is greater than 16 feet or the height is greater than 10 feet, a pilaster shall be interlocked near the center of the seal. The pilaster shall be at least 16 inches by 32 inches; and
iv. Coated on all accessible surfaces with flame-retardant material that will minimize leakage.

An alternative mine seal is any seal design other that the standard Mitchell-Barrett type seal. Both Sago and Kentucky Darby utilized Omega Block alternative seals.

MSHA implemented a moratorium on new construction of alternative mine seals designed to the federal regulatory 20 psi static horizontal pressure standard under Program Information Bulletin No. P06-11. As an interim measure, MSHA has set a temporary standard (Program Information Bulletin No. P06-16) requiring new alternative seal construction to be designed and built to reliably withstand an overpressure of at least 50 psi. To be considered for approval, designs and supporting data must be certified by a

professional engineer knowledgeable in structural engineering. In addition, the proposed ventilation plan must provide that a senior mine management official (e.g., mine manager, superintendent, etc.) certify that the construction, installation, and materials used were in accordance with the approved ventilation plan.

Both the Office of Mine Safety and Licensing and MSHA have initiated inspection and monitoring programs to evaluate existing alternative mine seals. Under inspection and monitoring programs, operators are required to document the condition of existing alternative mine seals and sample the atmosphere behind the seal. Remedial actions are not required if an alternative mine seal is in sound physical condition, properly constructed, and the mine atmosphere behind the seal is inert (less than 3 percent methane or more than 20 percent methane). If an alternative mine seal is in poor condition, damaged, or the mine atmosphere behind the seal contains from 3 percent to 20 percent methane, the operator must take remedial actions such as inerting the atmosphere, increasing the capacity of the existing seal, or the construction of a conventional Mitchell-Barrett mine seal.

The federal MINER Act directs the Secretary of Labor to finalize mandatory heath and safety standards relating to the sealing of abandoned areas in underground coal mines and to specifically provide for an increase in the 20 psi alternative seal design standard no later than 18 months after the issuance of a final report on the Sago Mine accident or the date of enactment.

It should be noted that the interim 50 psi overspressure standard for alternative seals may not contain a worst case explosion. Many factors influence blast pressures including entry geometry, volume of methane, and location of ignition source. Research suggests a methane explosion could exert up to 150 psi. A methane explosion coupled with coal dust could result in an even higher overpressure. The 50 psi overpressure standard was set utilizing a risk based approach. Future design standards need to balance seal practicality against continued ventilation and inspection of old workings which also has the potential to place miners at risk.

Recommendations

- The Office of Mine Safety and Licensing and MSHA have initiated inspection and monitoring programs to evaluate existing alternative mine seals designed to the previous 20 psi overpressure standard. Under inspection and monitoring programs, operators are required to document the condition of existing alternative mine seals and sample the atmosphere behind the seal. Remedial actions are not required if an alternative mine seal is in sound physical condition, properly constructed, and the mine atmosphere behind the seal is inert (less than 3 percent methane or more than 20 percent methane). If an alternative mine seal is in poor condition, damaged, or the mine atmosphere behind the seal contains from 3 percent to 20 percent methane, the operator must take remedial actions such as inerting the atmosphere, increasing the capacity of the existing seal, or the construction of a conventional Mitchell-Barrett mine seal. The Panel concurs with the overall inspection and monitoring program for existing alternative mine seals yet recommends continued periodic sampling of the atmosphere behind alternative seals by the operator to establish trending for individual seals.

- Mine management should be required to certify construction of mine seals in accordance with approved plans and regulations. MSHA Procedure Instruction Letter No. I-06-V-09 requires alternative seal construction, installation and materials to be certified by senior mine management (mine superintendent, or other equivalent mine official). The requirement to certify construction of alternative mine seals should be expanded to include conventional Mitchell-Barrett mine seals as safety concerns associated with improper seal construction exist regardless of seal type.

Related Safety Concerns

Background

Advancement in the field of mine safety technology has been limited due to a lack of research and development funding. The U.S. Department of Energy commissioned the National Research Council to undertake a study on required technologies for the Mining Industries of the Future Program. The overall objectives of the study were to review available information on the mining industry, identify critical research and development needs, and examine the federal contribution to research and development in mining processes. In the 2002 report *Evolutionary and Revolutionary Technologies for Mining,* the National Research Council made a strong case for federally funded research and development. The study committee noted:

> *Because of high capital requirements, small profit margins, the cyclic nature of commodity prices, long lead times for the development of new properties, and environmental constraints, the mining industry historically has been very conservative in initiating and adopting new technologies. Nevertheless, the industry has made significant advances in productivity, environmental control, and worker health and safety.*
>
> *The market will not support an optimal amount of research and development, possibly by a wide margin. Without government support, the private sector tends to underfund research and development, particularly high-risk projects with long-term payoffs.*
>
> *The USBM was the focal point for federal research in mineral technology from its inception in 1910 to its demise in 1996. Its accomplishments and contributions to the U.S. economy were significant.*
>
> *The federal government's current efforts in mineral technology are very small and unfocused. The mining industry continues to progress technologically, but*

many universities are finding it difficult to obtain funding for mining-specific research.

The federal government has an appropriate, clear, and necessary role to play in funding research and development on mining technologies. The government should have a particularly strong interest in what is sometimes referred to as high-risk, "far-out," "off-the-path," or "blue-sky" research. A portion of the federal funding for basic research and long-term development should be devoted to achieving revolutionary advances with the potential to provide substantial benefits to both the mining industry and the public.

Advancements in technology alone will not address all of the safety concerns in the mining industry. Mine safety and education training must parallel the emphasis placed on the development and utilization of new mine safety equipment. Given the necessary funding support, miners will then be presented not only with the best available safety equipment but also the training resources necessary to allow a safe work environment.

Recommendations

- The federal government and the Commonwealth of Kentucky need to develop a long-term funding mechanism to ensure continued research and development in the critical fields of mine safety and mine rescue technology. With the demise of the U.S. Bureau of Mines in 1996, the mining industry lost a centralized clearing house for many mining research initiatives. In this vacuum many areas of research, such as wireless mine communications, have not significantly advanced since initially analyzed by the Bureau in the preceding decades. The mining industry itself is a relatively small market which severely limits research and development funding in the private sector. Further complicating technological advancements are the numerous steps required to acquire regulatory certification prior to bringing a new product to market. There is a clear need for significant

government funding of research and development of emerging mine safety technologies.

- The federal MINER Act established the Brookwood-Sago Mine Safety Grant program to award competitive grants for education and training. Grants are to be utilized for education and training programs to better identify, avoid, and prevent unsafe working conditions in and around mines. The Congressional Budget Office's review of the MINER Act provisions anticipates funding of approximately $1 million annually over 2007-2011. This anticipated level of federal funding falls well short of the amount needed to further mine safety education and training efforts. The Panel recommends the federal government and the Commonwealth of Kentucky secure additional funding for the development of innovative miner education programs.

Mine Equipment Review Panel Members

- **Tim Watkins, Mine Safety and Health Administration.** Tim Watkins received a B.S. degree in Mining Engineering from the University of Kentucky in 1988. He has worked on mine safety at the Mine Safety and Health Administration since 1988 when he started as a Mining Engineer at the Denver Safety and Health Technology Center. Since then he has worked with mine ventilation at the Pittsburgh Safety and Health Technology Center and in MSHA's District 6 Office in Pikeville, Kentucky where he was Ventilation Supervisor from 2002 to 2005. In 2005, he was promoted to the position of Assistant District Manager for Technical Programs in District 6. He served eight years as a member of MSHA's Mine Emergency Unit and has participated in numerous mine emergency events across the nation. He is a licensed Professional Engineer in the state of Kentucky.

- **Mark Watson, Alliance Coal, LLC, coal industry representative.** Mark Watson has over 12 years of underground coal mining experience and has held positions in production, maintenance, engineering and management. In his current role of Vice President of Technical Services for Alliance Coal, LLC, Mr. Watson has been focused on applying new technologies to Alliance's underground operations for the purpose of enhancing safety and productivity. Mr. Watson holds both a Bachelor of Science degree and Masters of Science degree in Electrical Engineering from the University of Kentucky.

- **Edgar "Butch" Oldham, United Mine Workers of America, labor representative.** Butch Oldham started work as an underground miner in 1975 and worked underground until 1987. In 1987 he began working for the United Mine Workers of America as a Health and Safety Representative, the position he currently holds. He has been a member of the Kentucky Mining Board since 1989, and serves on the Illinois Mine Equipment Task Force. He holds certifications for Kentucky Certified Underground Mine Foreman, Kentucky

Certified Electrician Surface and Underground, Kentucky Certified Hoistman, and Kentucky Licensed Master Electrician.

- **Dr. Joseph Sottile, Department of Mining Engineering, University of Kentucky.** Joseph Sottile received the B.S., M.S., and Ph.D. degrees in Mining Engineering from The Pennsylvania State University, University Park, in 1984, 1987, and 1991, respectively. He has worked in production and engineering for the Barnes and Tucker Company from 1977 to 1983, and for Consol, Inc., in 1987. He is currently an Associate Professor of Mining Engineering at the University of Kentucky, Lexington. His teaching interests include electrical applications to the mining industry; his research interests include incipient failure detection of electrical components and safety and analysis of mine power systems.

- **Johnny Greene, Acting Executive Director, Office of Mine Safety and Licensing.** After graduating from Morehead State University, Johnny Greene began his mining career, spending 18 years working for mining companies such as Beth Elkhorn Coal, Chapperal Coal, Scotia and Golden Oak. In 1990 he was employed by the former Department of Mines and Minerals, where he has worked as Mine Safety Analyst, Mine Inspector, Inspector Principal, Acting District Supervisor, District Mine Rescue Trainer, Deputy Chief Accident Investigator, and State Mine Rescue Coordinator. He is currently Acting Executive Director for the Office of Mine Safety and Licensing.

Presentations before the Mine Equipment Review Panel

The Mine Equipment Review Panel wishes to acknowledge the individuals and organizations which shared their experience and expertise in mine safety technology with the Panel.

- Susan Bush, Commissioner, Department for Natural Resources
  - Overview of Senate Bill 200 and charge to the Panel
- Randall Harris, West Virginia Mine Safety Technology Task Force
  - West Virginia Mine Safety Technology Task Force recommendations
- Dave Chirdon, MSHA Electrical Safety Division and Technical Support
  - MSHA safety initiatives
- Wesley Shumaker, MSHA Approval and Certification Center
  - Emerging communication and tracking technologies
- Mike Koesterer, Mine Site Technologies
  Jason Schoff, CSE Corporation
  David Grimm, CSE Corporation
  - PED (Personal Emergency Device) Communication System
  - TRACKER Tagging System
  - VDV Leaky Feeder System
- Walt Slomski, General Engineer, MSHA Approval and Certification Center
  Bill Barnwell, Mine Safety and Health Specialist, MSHA Approval and Certification Center
  - Mine refuge chamber design and function
- Lanny Oblinger, Lad Mining Ventilation Services, Inc.
  Mike Thompson, Jack Kennedy Metal Products
  Randy K. Harlan, United Central Industrial Supply
  - Kennedy Chamber mine refuge chamber

- T.J.Pitzer, Draeger Safety
  Larry McCoy, Draeger Safety

  - Draeger Refuge Shelter
  - Quick Fill Station self-contained breathing apparatus

- Jeff Kravitz, MSHA, Chief, Mine Emergency Operations

  - Self-Contained Self-Rescuer design and function
  - Next Generation SCSRs

- Kelvin Wu, MSHA Pittsburgh Safety and Health Technology Center

  - Mine Seal design and function
  - Mine Refuge Chamber design and function

- Braden Lusk, Department of Mining Engineering, University of Kentucky

  - Effects of Underground Explosions

- Rory Paton Ash, Strata Products, Inc.
  Lester Tupper, Strata Products, Inc.

  - Shairzal Emergency Refuge Station
  - Portable Fresh Air Bay